Thermal Simulations of Thin Solid Carbon Foils for Charge Stripping of High Current Uranium Ion Beams at New GSI Heavy-Ion Linac*

N.A. Tahir[1], *V. Kim*[2], *W. Barth*[1], *L. Groening*[1], *I.V. Lomonosov*[2], *A.R. Piriz*[3], *B. Schlitt*[1], *Th. Stöhlker*[1,4], *and H. Vormann*[1]

[1]GSI, Darmstadt, Germany; [2]IPCP, Chernogolovka, Russia; [3]UCLM, Ciudad Real, Spain; [4]IOQ Friedrich-Schiller Universität and Helmholtz Institute, Jena, Germany

This paper presents an extensive numerical study of heating of thin solid carbon foils by 1.4 MeV/u uranium ion beams to explore the possibility of using such a target as a charge stripper at the proposed new GSI high energy heavy–ion linac. These simulations have been carried out using a sophisticated 3D computer code that accounts for physical phenomena that are important in this problem. The stripper is assumed to be a thin circular foil of solid graphite with density 2.28 g/cm^3 and radius, R_f = 1.5 cm while the uranium beam is incident perpendicular to its surface. Three different foil thicknesses including 20, 30 and 40 μg/cm^2, have been considered.

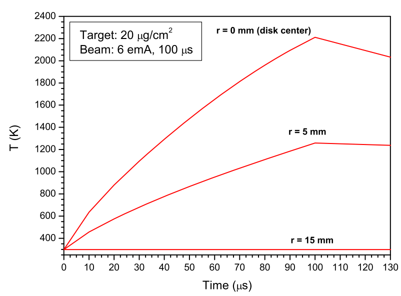

Figure 1: T vs time (during pulse length) at different points along foil radius, foil thickness = 20 μg/cm^2, current 6 emA and pulse length = 100 μs.

Two different current values, namely, 6 emA and 18 emA have been used where the latter is the FAIR design value. A pulse length of 100 μs is considered that leads to pulse intensities, N = 9.375 $\times$ 10^{11} and 2.8125 $\times$ 10^{12} for the beam current values of 6 emA and 18 emA, respectively. The transverse particle distribution in the focal spot is assumed to be Gaussian with σ = 3.67 mm, whereas the repetition rate of the ion beam pulses is 2 Hz.

The initial charge state is U^{4+} while the ion is stripped to a charge state of U^{39+} after passing through either 20 or 30 μg/cm^2 thick stripper foils. A slightly higher charged state of U^{40+} is achieved with a 40 μg/cm^2 thick foil. For simplicity, we assume in the calculations a uniform ion charge state along the foil thickness (39+ in case of 20 and 30 μg/cm^2 and 40+ in case of 40 μg/cm^2 thickness). In practice, however, there will be an exponential type charge distribution along the ion trajectory.

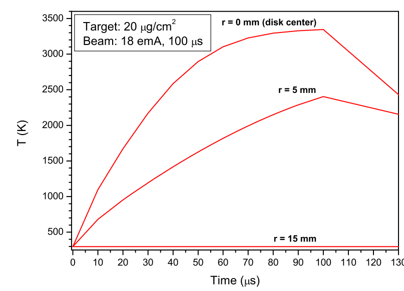

Figure 2: Same as in Fig. 1, but using beam current 18 emA

In Fig. 1 we plot the temperature for 6 emA current at three different points along the foil radius, namely, r = 0 (center), 5 mm and 15 mm (outer boundary), respectively. It is seen that a maximum temperature of around 2200 K is achieved at the target center at the end of the pulse (100 μs), whereas the maximum temperature at r = 5 mm is about 1250 K. The temperature at the foil boundary, on the other hand, does not change. It is to be noted that although the sublimation temperature of carbon in air is much higher (3925 K), the target could be damaged due to the induced thermal stresses [1,2]. The corresponding temeprature at the foil center in case of 30 and 40 μg/cm^2 is 2300 K and 2400 K, respectively. This is because diffusion of heat from the target center to the surface takes longer time that reduces the cooling rate.

In Fig. 2 we plote the same variables as in Fig. 1, but using 18 emA current. It is seen that the temperature at the foil center approaches the carbon sublimations temperature which means that it will not survive a single irradiation in this case. For 30 and 40 μg/cm^2 foil thickness, the maximum temperature is even higher. It is therefore concluded that use of a solid stripper foil is not feasible at the new high energy drift tube linac at GSI. Further details can be found in [3]

References

[1] N.A. Tahir et al., NIMB 276 (2012) 66.

[2] N.A. Tahir et al., NIMB 290 (2012) 43.

[3] N.A. Tahir et al., PRSTAB (2014) Submitted.

* Work supported by the BMBF